# Applications Overview of IHDIV NSWC's Reactive Materials


Brian Amato
301-744-1414
Brian.Amato@navy.mil

Carl Gotzmer
301-653-1000
carl.gotzmer@navy.mil

Steve Kim
301-744-1275
steven.s.kim@navy.mil

# Report Documentation Page

*Form Approved*
*OMB No. 0704-0188*



| 1. REPORT DATE | 2. REPORT TYPE | 3. DATES COVERED |
|---|---|---|
| **APR 2009** | | **00-00-2009 to 00-00-2009** |

| 4. TITLE AND SUBTITLE | 5a. CONTRACT NUMBER |
|---|---|
| **Applications Overview of IHDIV NSWC's Reactive Materials** | 5b. GRANT NUMBER |
| | 5c. PROGRAM ELEMENT NUMBER |
| 6. AUTHOR(S) | 5d. PROJECT NUMBER |
| | 5e. TASK NUMBER |
| | 5f. WORK UNIT NUMBER |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br>**Naval Sea Systems Command (NAVSEA),Naval Surface Warfare Center, Indian Head Division,Indian Head,MD,20640** | 8. PERFORMING ORGANIZATION REPORT NUMBER |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | 10. SPONSOR/MONITOR'S ACRONYM(S) |
| | 11. SPONSOR/MONITOR'S REPORT NUMBER(S) |

12. DISTRIBUTION/AVAILABILITY STATEMENT
**Approved for public release; distribution unlimited**

13. SUPPLEMENTARY NOTES
**Presented at National Capital Region Energetics Symposium, La Plata, MD, April 27-28, 2009.**

14. ABSTRACT

15. SUBJECT TERMS

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| a. REPORT | b. ABSTRACT | c. THIS PAGE | | | |
| **unclassified** | **unclassified** | **unclassified** | **Same as Report (SAR)** | **14** | |

# What are Reactive Materials?

- **Reactive Materials" refers to materials that either react with themselves (thermites, intermetallics) or combust violently with air (Al, Ti, Hf) upon impact releasing energy.**
  - **An energetic material consisting of two or more solid-state reactants that together form a thermo-chemical mixture**
  - **Typically metal-metal and/or metal-metal oxide mixtures with and without binders**
  - **Materials with higher predicted energy per unit volume than conventional energetics**
  - **Energy release management is critical to obtain useful energy from RMs**
    - **RM formulation (particle size, density, structural properties etc..)**
    - **System engineering**

**ENERGY COMPARISON**

| Composition | (-ΔH) [cal/g] | (-ΔH) [cal/cm3] |
|---|---|---|
| TNT | 1,040 | 1,530 |
| HMX | 1,280 | 2,510 |
| Ti+2B | 1,115 | 3,992 |
| 2 Al + 3 H2O | --- | 10,154 |
| C+O2 | 2,800 | 17,600 |
| 4Al+3O2 | 7,420 | 20,040 |
| | | |

# Classes of Reactive Materials

- Self-Propagating High-temperature Synthesis (SHS) - **more energy**
  - Thermitic - metal/metal oxide reactions
    - Thermite and MIC reactions
  - Intermetallic reactions
    - Aluminides
    - Borides
    - Carbides
  - Metal/fluorine systems

- Ultra-fine powders - **energy management**
  - ALEX (exploded wire)
  - MIC ingredients
  - Nano-laminates
  - Mechanochemical Synthesis (MCS)
  - Energy Saturated Media (ESM)
  - Hf and Ti powders

NAVSEA WARFARE CENTERS INDIAN HEAD

# Potential Applications

- Biological agent defeat
- Material destruction
- Target damage using structural reactives
  - Reactive fragments
  - Enhanced blast effects
- High Explosive Target Countermeasure
- Improved underwater explosives
- Manufacturing
- Metal cutting/concrete cutting
- Propellant/Explosive additives

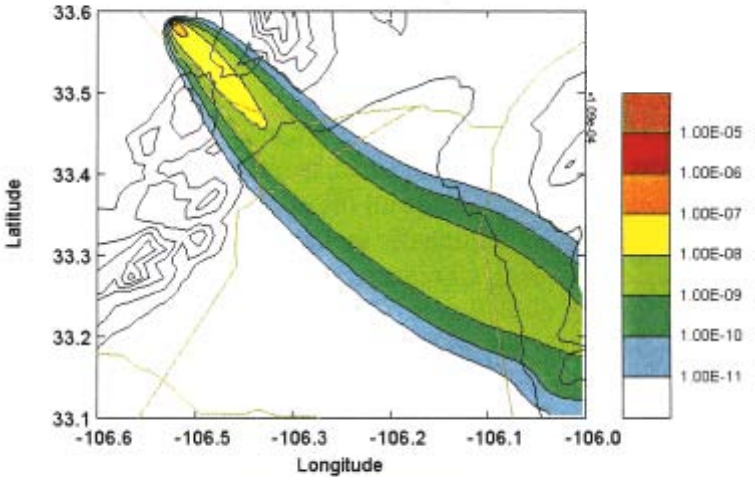
IHDIV DoD ENERGETICS CENTER Excellence for the Warfighter

# Advantages of an RM

- Additional energy by replacing inert components with an RM
- Adaptable to a variety of applications
- Offers kill mechanisms that resulting in lower collateral damage
- Many RMs are 4.1 Flammable solid versus 1.1 detonable explosives
- Improved Insensitive Munitions (IM) sensitivity
- Minimal gas evolved during combustion
- Warhead fill would survive high impacts from penetration

# Biological Agent Defeat Application

**HIGH EXPLOSIVE BOMB ATTACK ON BIOLOGICAL TARGET**




- **HE overpressure and target damage will result in large release of live agents and massive collateral damage downwind.**

**1 GRAM**
**10 BILLION SPORES**

**8,000 Spores**
**50 % Lethal**

**Anthrax Spores**

# Biological Agent Defeat Application

- **RMs that produce a long thermal pulse, low overpressure and biocides will be effective against biological agents.**
- **In FY2005, IHDIV NSWC demonstrated the Vulcan Fire intermetallic / oxidizer payload against Anthrax simulant during the Agent Defeat ACTD Program**

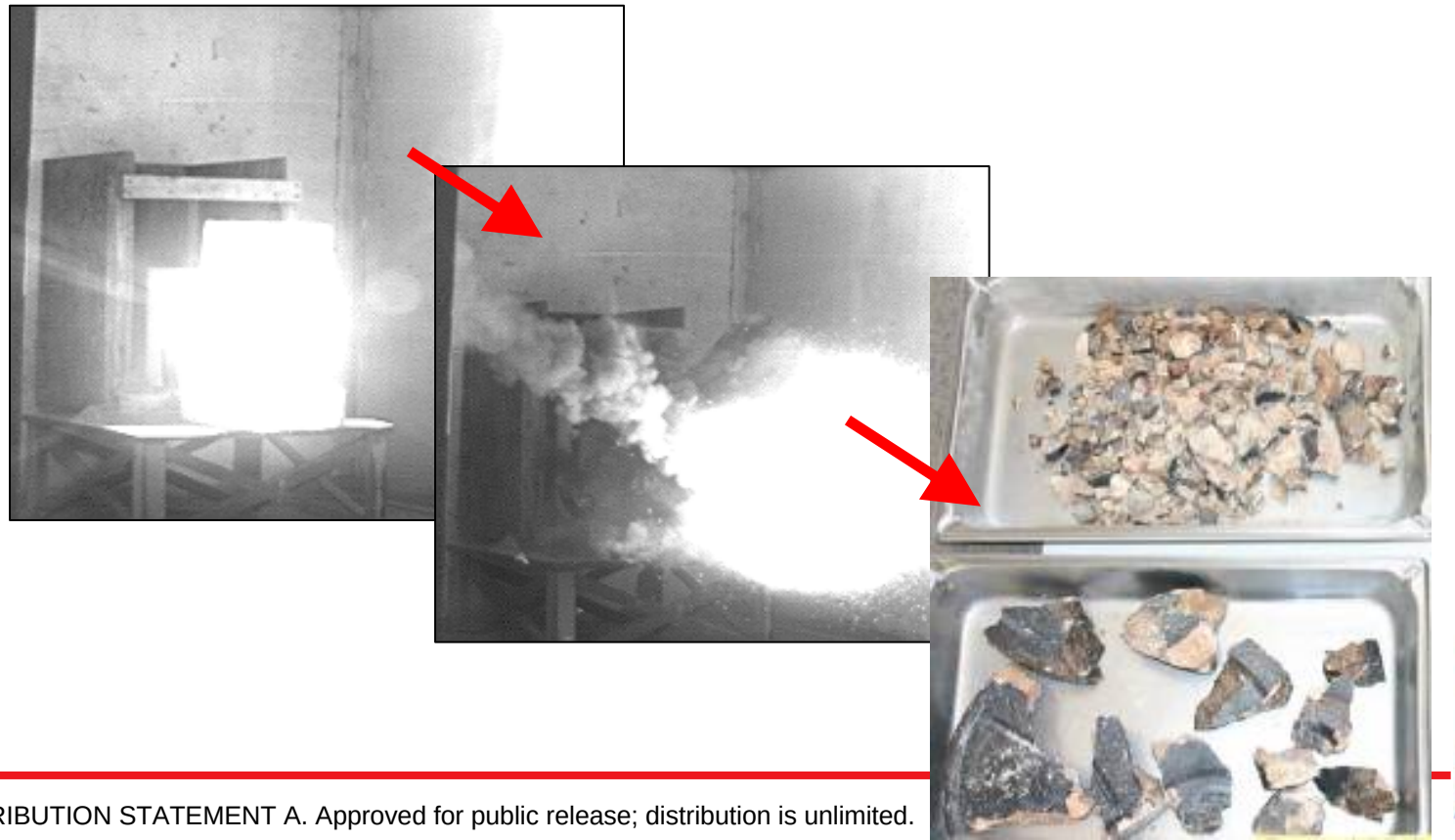
**• FY2005 Military Utility Assessment (MUA) of RM payload for USECENTCOM**


**Effective Kill Environment**

- **Sustained target temperature >500F**
- **Biocides created**
  - **$Cl_2$, and Titanium Dioxide**
- **Very low overpressure**

# High Explosive Target Countermeasure Application

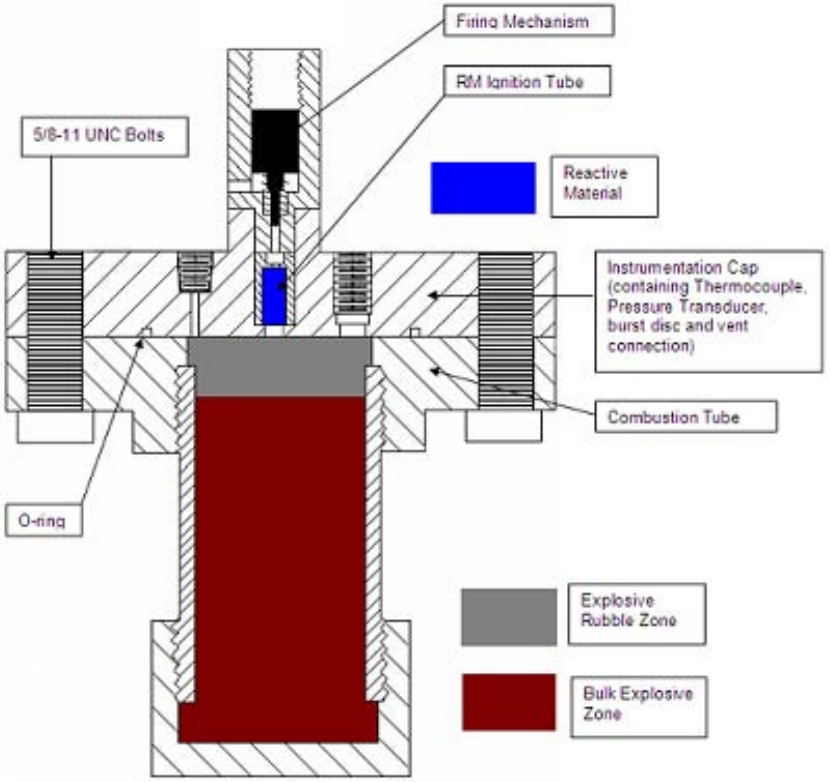
- RMs may be effective countermeasure to HE targets. The goal is to identify RM candidates that can destroy these targets with minimal collateral damage
  - Maximize target break-up and combustion
  - Prevent target detonation response



# High Explosive/RM Characterization

- **Test chamber simulates HE target impacted by RM projectile. It incorporates an HE bulk and rubble zone to simulate impact damage.**
  - **Data Collection**
    - **Temperature vs Time**
    - **Pressure vs Time**
    - **Chamber damage serves as a witness to HE response**
    - **HE consumption**
  - **Scalable**
    - **Chamber was sized to hold ~380g but can be scaled**

HE/RM Test Chamber




Bulk & Rubble HE Loading

# Material Destruct Application

- Sustained high temperature is required to destroy materials. An RM producing high overpressure is not desired.
- The Vulcan Fire (VF) intermetallic RM with and without oxidizer was demonstrated for material destruct application.

Manportable VFThermal Radiator

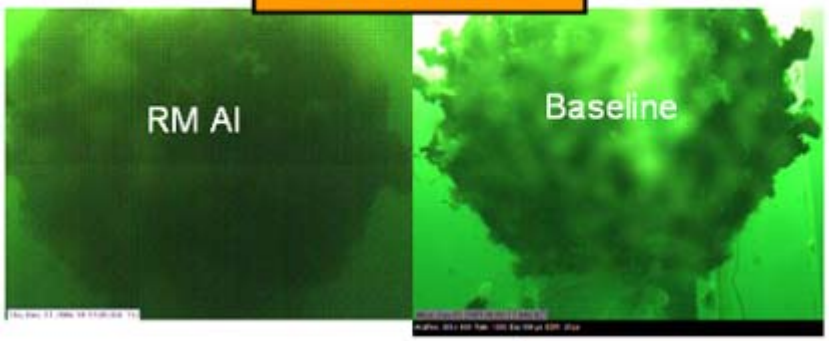
Vulcan Fire Thermal Radiator Cave Test

Vulcan Fire Burn Barrel Test

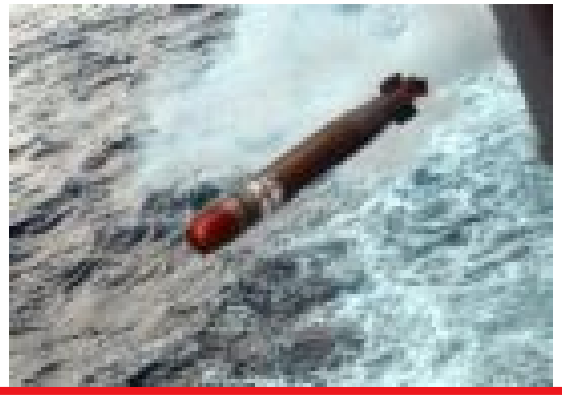
# Underwater Warhead Application

- Increase underwater warhead performance by reacting water with an RM.
- The challenge is to react and mix RM with external water fast enough to support shock impulse and bubble.
- Small scale tests conducted in FY09 indicate that the aluminum-water reaction was fast enough to increase shock impulse and bubble energy.

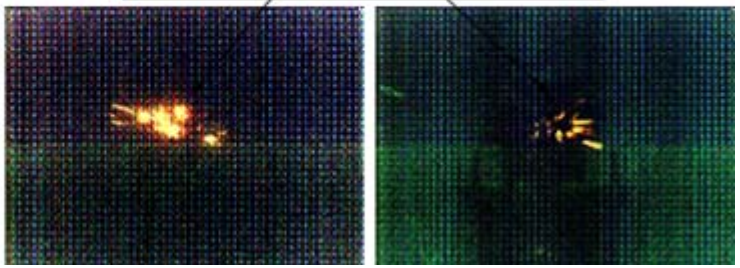
Bubble Photos




UNDEX Tank



RM Aluminum-Water Reactions

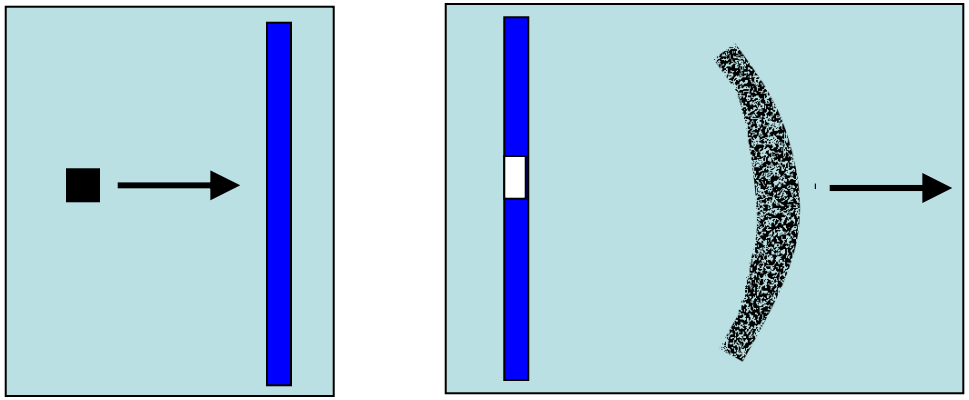


# Structural RM Applications

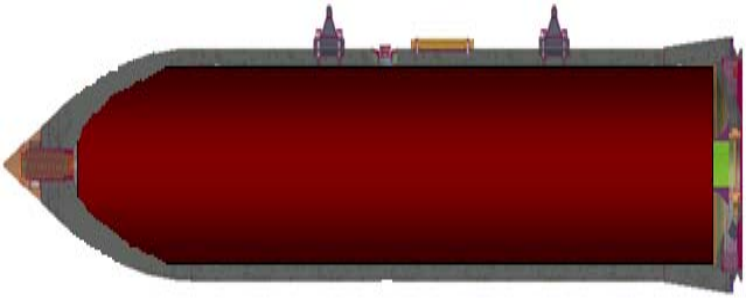
***Reactives augment Kinetic Energy Effects with Chemical Energy to Enhance Lethality and Battle Damage Indication.***

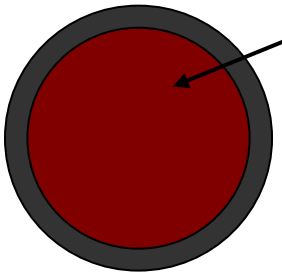
- **IHDNSWC has developed the highest performing RMs with densities >5.5 g/cc. Goal is to increase density to steel (7.8 g/cc)**
  - **For a reactive fragment impacting a target, the break-up and react as a FAE inside the target**
  - **For enhanced blast, an RM case will immediately breakup during HE event and react as a FAE**

REACTIVE FRAGMENTS

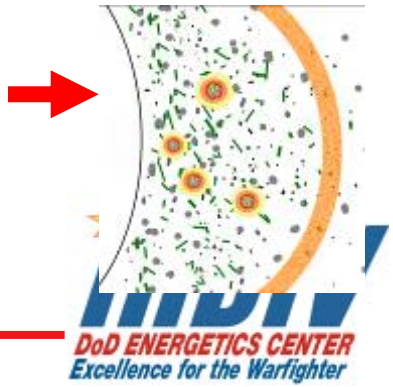


ENHANCED BLAST WARHEAD CASING





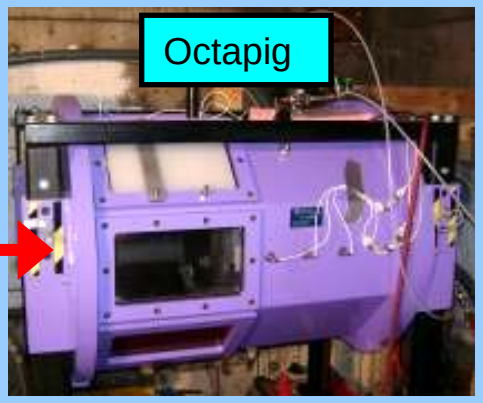
***HE detonation disperses Structural RM and initiates fuel/air combustion with heated/dispersed RM particles resulting in increased blast.***

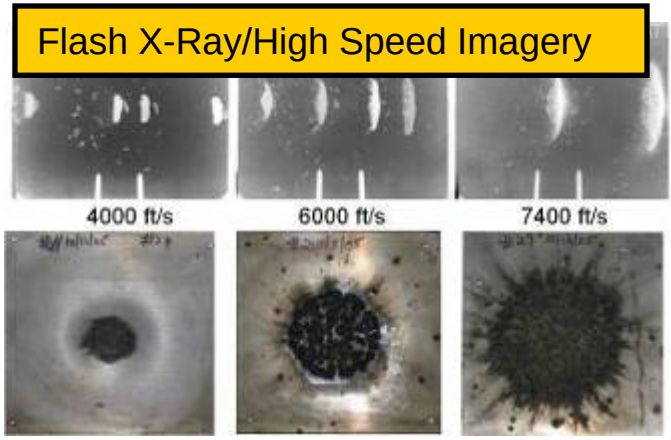


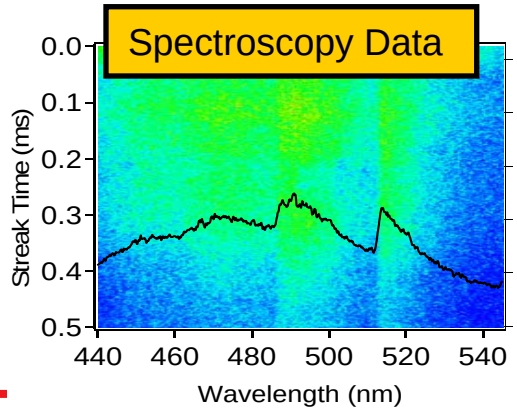
# Reactive Materials Energy Release Characterization

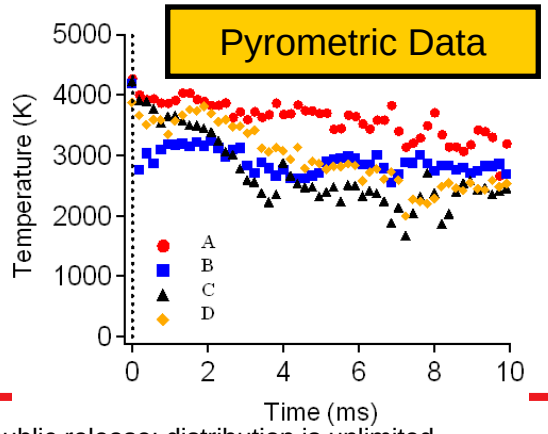
*PI – Jason Jouet, PhD, Code R11JJ, 301-744-4212, Jason.Jouet@Navy.mil*
*PI – Dr. Richard Lee, PhD, Code R12RL, 301-744-2380, Richard.j.lee@Navy.mil*

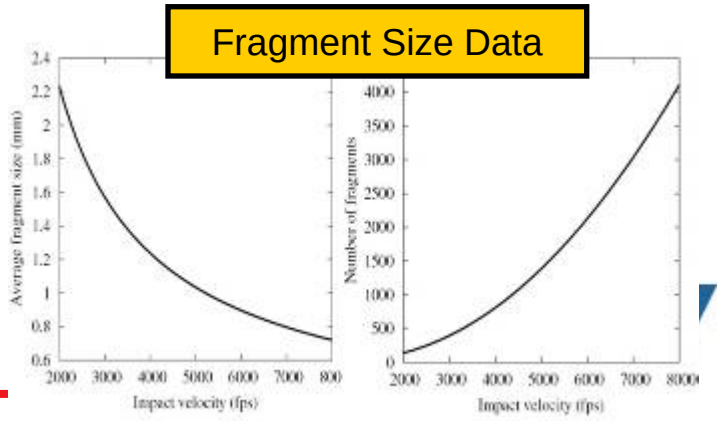
- **RMs are fired from 1K to 8K ft/sec. They penetrate thin steel plate and break up finally impacting on anvil in test chamber.**
- **We can collect peak and quasistatic pressure data, spectroscopy data, pyrometry data, flash x-ray images, high speed optical photography, reaction gas sampling, and RM debris collection in a single shot.**
- **Quasistatic pressure generally accepted as performance metric.**

# Points of Contact (POC)


- Carl Gotzmer, Code TM3**,** Carl.Gotzmer@Navy.Mil, (301) 653-1000
- Brian Amato, Code E123A, Brian.Amato@Navy.Mil, (301) 744-1414
- Steven Kim, Code E123B, Steven.S.Kim@Navy.Mil, (301) 744-1275



- Acknowledgements
  - Jason Jouet, PhD, Code R11JJ, Jason.Jouet@Navy.Mil, (301) 744-4212
  - Richard Lee, PhD, Code R12RL, Richard.J.Lee@Navy.Mil, (301) 744-2380